UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Hybrid Power Plant Bidding Strategy for Electricity Market Participation

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Thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

under the supervision of Li Li, Jiangfeng Zhang, and Jianguo Zhu

University of Technology Sydney
Faculty of Engineering and Information Technology

August 2019

Title of the thesis:

Hybrid Power Plant Bidding Strategy for Electricity Market Participation

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Certificate of Original Authorship

I, Sahand Ghavidel Jirsaraie declare that this thesis, is submitted in fulfillment of the requirements for the award of doctor of philosophy, in the School of Electrical, Mechanical and Mechatronic Systems, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian government research training program.

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Date: 11/05/2020

Acknowledgments

I would express my sincere gratitude to my principal supervisor Dr. Li Li, for his guidance and encouragement during my study. I also would like to thank my other supervisors, Dr. Jiangfeng Zhang and Prof. Jianguo Zhu for their help and advice.

I am incredibly thankful to my friend Mostafa Barani. He discussed research points in details and gave me insightful advice.

I want to thank my friends and colleagues, Mojtaba Jabbari Ghadi, Amin Rajabi, and Ali Azizivahed, for their support in daily life.

Finally, my sincerest thanks go to my families. Without their strong understanding and support, it is not possible for me to complete this thesis.

Publications and Conference Contributions

The following publications are part of the thesis.

Peer-reviewed international journal publications

[1] **S. Ghavidel***, A. Azizivahed, and L. Li, "A hybrid Jaya algorithm for reliability–redundancy allocation problems," *Engineering Optimization*, vol. 50, no. 4, pp. 698-715, 2018. (***Published***)

[2] **S. Ghavidel***, MJ. Ghadi, A. Azizivahed, J. Aghaei, L. Li, J. Zhang, Risk-Constrained Bidding Strategy for a Joint Operation of Wind Power and Compressed Air Energy Storage Aggregators. *IEEE Transactions on Sustainable Energy*, 2019 (***Published***)

[3] **S. Ghavidel***, A. Rajabi, MJ. Ghadi, A. Azizivahed, L. Li, J. Zhang, Risk-Constrained Demand Response and Wind Energy Systems Integration to Handle Stochastic Nature and Wind Power Outage, *IET Energy Systems Integration*, 2018 (***Published***)

Peer-reviewed international scientific conference publications

[4] **S. Ghavidel***, MJ. Ghadi, A. Azizivahed, M. Barani, J. Aghaei, L. Li, J. Zhang, "Hybrid power plant bidding strategy including a commercial compressed air energy storage aggregator and a wind power producer," in *Universities Power Engineering Conference (AUPEC)*, 2017 Australasian, 2017, pp. 1-6: IEEE.

[5] **S. Ghavidel***, M. Barani, A. Azizivahed, M. J. Ghadi, L. Li, and J. Zhang, "Hybrid power plant offering strategy to deal with the stochastic nature and outage of wind

generators," in *Electrical Machines and Systems (ICEMS)*, 2017 20th International Conference on, 2017, pp. 1-6: IEEE.

[6] **S. Ghavidel***, L. Li, J. Aghaei, T. Yu, and J. Zhu, "A review on the virtual power plant: Components and operation systems," in *IEEE International Conference on Power System Technology*, 2016: IEEE.

Abstract

In this thesis, the strategies of hybrid power plants (HPPs) in electricity markets to minimize the impacts of wind power uncertainties through storage and demand managements are investigated.

Firstly, a commercial Compressed Air Energy Storage (CAES) aggregator equipped with a simple cycle operation mode is correlated with a Wind Power Aggregator (WPA) as an HPP to participate in electricity markets. The WPA utilizes the CAES to tackle wind power forecasting errors and uncertainties associated with different electricity market prices, while CAES can get assistance from WPA to schedule its charging/discharging and simple cycle modes more economically. A three-stage stochastic decision-making method is formulated to model the proposed optimization problem. Besides, conditional value-at-risk (CVaR) is added to the model to control the financial risk of the problem and offer different operation strategies for different financial risk levels. It also provides both bidding quantity and bidding curves to be submitted to the electricity markets.

Secondly, an offering strategy with a three-stage stochastic programming is presented for an HPP, which includes a WPA and a Demand Response Aggregator (DRA). Three electricity markets are considered including DA, intraday, and balancing market for the joint operation of WPA and DRA as an HPP. The CVaR is also added to the HPP offering strategy to control the profit risk. The offering strategy for the second case study is tested in a wind farm and electricity market located in Spain. The result shows that the HPP offering strategy can effectively assist the balancing and outage problem of the WPA and increase the overall profit of the joint operation.

Finally, an HPP, including a CAES aggregator with a WPA is modeled considering network constraints. Three objective functions are considered including electricity market maximization, congestion management, and voltage stability improvement. In order to accurately model the WPA, pitch control ability is added to wind generator models to control the wind power curtailment level. Multi-objective Pareto front solutions are considered to optimize all the mentioned objective functions properly, and finally, the best solution is suggested using the fuzzy method. The proposed approach is tested on a realistic case study based on a wind farm and electricity market located in Spain, and the IEEE 57 bus test system is used to analyze the network constraint effects on the HPP scheduling for different objective functions.

Keywords: Hybrid Power Plant; Wind Power Aggregator; Demand Response Aggregator; Compressed Air Energy Storage Aggregator

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Nomenclature

Global abbreviations used in this thesis:

ADN	Active Distribution Network
BESS	Battery Energy Storage System
CAES	Compressed Air Energy Storage
CHP	Combined Heat And Power
CHP	Coupled with District Heating (CHP–DH)
CVaR	Conditional Value-at-Risk
CHPP	Commercial HPP
DA	Day-Ahead
DG	Distributed Generation
DR	Demand Response
DRP	Demand Response Provider
DRRs	Demand Response Resources
DSO	Distribution System Operator
EDLC	Electric Double-Layer Capacitors
EDLC	Electric Double-Layer Capacitors
EMS	Energy Management System
FERC	Federal Energy Regulatory Commission
FES	Flywheel Energy Storage
HPES	Hydraulic Pumped Energy Storage

HPP	Hybrid Power Plant
PEM	Point Estimate Method
PEVs	Plug-In Electric Vehicles
PHEVs	Plug-In Hybrid Electric Vehicles
SMES	Superconducting Magnetic Energy Storage
TSO	Transmission System Operator
THPP	Technical HPP
HPP	Hybrid Power Plant
WPA	Wind Power Aggregator